CHAPTER 11:

CONCLUSION

In this book, we have presented a systematic study of women in science and engineering. Following a life course approach, our study traces gender differences along the career process of becoming a scientist/engineer as well as in career outcomes among scientists/engineers. The life course approach has led us to recognize that science/engineering careers are multi-faceted in nature and are affected by multi-layered influences at the individual, familial, and social levels. We illustrated the multi-faceted nature of S/E careers through our examination of a few important aspects of S/E career processes and outcomes: the attainment of S/E education, career transitions following the completion of undergraduate and graduate S/E education, labor force participation, earnings, promotion, geographic mobility, immigration, and research productivity.

Our research addresses gender differences in the processes and outcomes of S/E careers with detailed statistical analyses of data drawn from seventeen large, nationally representative datasets. Summarizing the findings across these analyses is not an easy task. If we were asked to give a one-word summary, it would be *complexity*: We have found that gender differences in S/E career processes and outcomes are extremely complex, and this complexity necessitates careful and detailed analyses such as those presented in this book. No simplistic explanation should or could substitute for the richness of the empirical results from these analyses. In this concluding chapter, we aim to highlight some of the major findings of the study and discuss their implications.

Major Findings

As discussed in Chapter 1, there is already a sizable literature on women in science. One of the important tasks of our study was to provide an empirical evaluation, with updated data and appropriate analytical methods, of the key hypotheses and claims widely accepted in the literature and commonly believed by the scholarly community and the general public alike. Surprisingly, we found clear evidence rejecting many of these hypotheses and claims.

One of the longstanding hypotheses in the literature is that women are less likely to pursue S/E careers because they are handicapped by deficits in high school mathematics training. For example, discussing career barriers for both minorities and women, Sells (1980, p.66) claims that "[a] student's level of high-school mathematics achievement acts as a critical filter for undergraduate college admission for blacks and limits choices of an undergraduate major for women in general once they are admitted to college." Although this hypothesis is appealing for its simplicity and the clear remedy it implies, it has not been subjected to a rigorous empirical test. We conducted the analyses in Chapters 2 through 4 in part to test this "critical filter" hypothesis. Two findings emerged: (1) the gender gap in average mathematics achievement is small and has been declining, although boys remain much more likely than girls to attain very high levels of competence; (2) gender differences in neither average nor high achievement in mathematics explain young men's higher likelihood of majoring in S/E fields in college relative to young women. Thus, the empirical results of our study lead us to reject this hypothesis.

A different version of the same hypothesis focuses on math and science coursework. It argues that, since preparation for a science career begins in high school (or before), participation and high performance in high school math and science courses are essential for entry into the S/E career trajectory. This idea is commensurate with and reinforced by the science pipeline perspective that equates membership in the pool of potential scientists with participation in the orderly sequence of high school math and science courses. This "coursework hypothesis," as articulated by Alper (1993, p.410), states that "[b]y the time ... young women graduate high school, they have taken so many fewer math and science courses that it precludes significant numbers of them from pursuing college science and engineering majors." The idea that girls are less likely to pursue S/E majors in college and to become scientists and engineers because they fail to participate in the requisite math and science college preparatory courses during high school is explicitly tested and refuted in Chapters 3 and 4. We found that girls are not only on par with boys in course participation, but they also attain significantly better grades for their science and math coursework. Not surprisingly, we find that coursework participation and performance cannot account for gender differences in expectations of and participation in S/E college majors.

In the first chapter, we challenged the prevailing "pipeline" paradigm in the women in science literature as a fruitful conceptualization of the career trajectory. In Chapter 4, we provided concrete evidence demonstrating the drawbacks of the pipeline conceptualization. In contrast to the rigid "leaking only" career path dictated by the pipeline metaphor, we showed that career processes are fluid and dynamic, with exit, entry, and reentry all being real possibilities at any given point in a career. While this approach was earlier proposed by Xie (1996), the analysis presented in Chapter 4 is far more comprehensive. Contrary to what might be expected according to the pipeline paradigm, we found that most women recipients of S/E bachelor's degrees had actually expected to pursue a non-S/E college major but later shifted to the S/E track during college.

It is widely known, and shown in Chapters 7 and 8, that women scientists are more likely than men to be situated in dual-career marriages. It has been suggested in the literature that the constraints of this marriage pattern contribute to women scientists' low rates of geographic mobility (Marwell, Rosenfeld, and Spilerman 1979; Mincer 1978). However, as we argued in Chapter 8, this view is too simplistic. It overlooks the addition of job-related mobility opportunities associated with two careers in a family. Indeed, our analysis in Chapter 8 shows that women scientists of any marital status are not necessarily less mobile than their male counterparts. We found that gender differences arise only when children are present. More specifically, it is among scientists with young children that men have higher rates of mobility than women.

Another well-known stylized "fact" in the women in science literature is that women academic scientists have lower rates of research productivity than men. In the words of Cole and Zuckerman (1984, p.217), "women published slightly more than half (57%) as many papers as men." For a long time, this gender gap in research productivity could not be explained and was widely accepted as the "productivity puzzle." In Chapter 9, we conducted a multivariate analysis of four nationally representative datasets on postsecondary faculty that were collected in 1969, 1973, 1988, and 1993. Our analysis yielded two primary findings. First, sex differences in research productivity declined over the time period studied, with the female-to-male ratio increasing from about 60 percent in the late 1960s to 70 percent in the late 1980s and about 80 percent in the early 1990s. Second, most of the observed sex differences in research productivity can be attributed to sex differences in personal characteristics and structural positions. These results suggest that sex differences in research productivity are not immutable. Rather, they stem from sex differences in structural locations and as such respond to the improvement of women's position in science.

A common theme that runs through several chapters in the book is the importance of considering the family in studies of women in science. In particular, we find that it is not marriage per se that hampers women's career development. Rather, married women appear to be disadvantaged only if they have children. Relative to their male counterparts, married women with children are less likely to pursue careers in science and engineering after the completion of S/E education (Chapters 5 and 6), less likely to be in the labor force or employed (Chapter 7), less likely to be promoted (Chapter 7), and less likely to be geographically mobile (Chapter 8). Although some of the gender differences are attributable to the advantages that marriage and parenthood bestow upon men, they clearly suggest that being married and having children create career barriers that are unique to women scientists.

Our research on immigrant scientists is also consistent with the notion that the family plays a distinct role in generating gender differences among immigrant scientists/engineers. In Chapter 10, we found that women immigrant scientists are more severely disadvantaged than native-born women scientists in employment as well as in opportunities for promotion. By comparison, immigrant men scientists fare well relative to their native-born counterparts. Although we do not have the data to verify the explanation, we attribute these differences to the distinct immigration paths taken by women and men scientists. While men scientists are more likely to be primary immigrants, women scientists are more likely to be secondary immigrants as spouses of primary immigrant husbands. In light of our findings, we echo Pedraza's (1991) call for considering both the "public" and "private" spheres when studying women immigrants. In the future, more research attention should be devoted to the special circumstances experienced by immigrant women scientists—such as their migration paths.

Finally, we have found individual "choice" to be a powerful determinant of gender differences in S/E careers. We put the quotation marks around the word "choice" because we do not believe that choices are necessarily voluntary and/or perfectly rational. On the contrary, career choices always reflect the broad social structure and as such reinforce the current gender segregation of occupations (Marini and Brinton 1984; Xie and Shauman 1997). In Chapter 3, we showed that educational aspirations expressed in high school are gendered, with girls less likely to be interested in pursuing S/E than boys. We further demonstrated in Chapter 4 the consequences of the gender differences in educational aspirations for the actual attainment of S/E education. In Chapters 5 and 6, we showed that a large portion of the aggregate gender differences in career outcomes is attributable to the sex segregation of fields within science and engineering. Clearly, gender equality cannot be achieved as long as women scientists disproportionately "choose" some fields (such as biological science) and avoid others (such as engineering and physical science).

Implications

The results from our study reaffirm our proposition that the career processes and outcomes of women in science are best understood from the perspective of the life course. The benefits of adopting the life course perspective are clear from the analyses we have conducted. For example, while this perspective recognizes that past experiences and "choices" clearly influence the future direction of one's life course, it emphasizes that the interdependence is not a deterministic one. In this sense, the life course perspective directed our attention to the full range of possible life course pathways rather than to those that are most often traveled. The life course perspective also encouraged us to take a broad approach to identifying the factors that influence the individual events and cumulative outcomes. By examining the S/E career trajectory within the broad context of other life course events, we have specified the multiple and interdependent influences of the family as well as the institutional structures on the career experiences and outcomes of men and women in science.

The insights gained from the life course perspective highlight the limitations of the dominant pipeline paradigm. For example, according to the pipeline paradigm, entry into the S/E educational trajectory is an insignificant route to S/E careers, and for this reason past research has largely ignored it and instead has focused on the "leaks" from the S/E trajectory. In practice, policies are typically formulated to increase persistence among those already involved in the S/E educational trajectory rather than to entice students into S/E majors during college. This policy focus is called into question by two findings of our analysis in Chapter 4. First, a significant proportion of students attain S/E bachelor's degrees by shifting from the non-S/E track to the S/E track sometime after high school graduation. Second, gender differences in the prevalence of this "non-conventional" path to S/E account for almost half of the gender differences in S/E degree attainment. Both of these findings suggest that efforts to institutionally facilitate the flow of high school students who expected non-S/E college majors into S/E majors during the first year of college may significantly reduce the gender gap in the attainment of S/E bachelor's degrees.

In our effort to contextualize the S/E educational and occupational trajectory, we showed how the career processes and outcomes of women scientists and engineers are intertwined with and influenced by other aspects of their lives. In particular, the results concerning the importance of the family reveal particular challenges that women face in combining an S/E career and family. In contrast, our results indicate that having a family seems to be a career boost to men scientists and engineers. This conclusion is consistent with the larger literature that addresses the dilemmas faced by professional women pursuing competitive careers in the contemporary United States (Blau 1998; Goldin 1990; Spain and Bianchi 1996). On the surface, it appears that the interaction between gender and family status simply indicates the traditional within-household gender stratification in which the wife's career is often sacrificed for the benefit of the husband's career. Our empirical results, however, call for a more precise and more qualified interpretation. We have shown that it is not being married per se, but being married and having children, that hampers women's careers. Perhaps the past debate on women scientists focused wrongly on the balance between maximizing the husbands' versus wives' careers. Our research suggests instead that, as long as the primary responsibility for childcare continues to fall on the shoulders of women, the real dilemma facing the woman scientist is the choice between maximizing her own career and her responsibility for her children's well-being.[1]

The complex and multi-faceted nature of women scientists' career processes and outcomes and their close relationship to other life course events make it very difficult to recommend policy interventions intended to increase women's representation in science and engineering. To be sure, such interventions have been proposed and implemented in the past (see, for example, Matyas and Dix 1992). However, these programs have not been based on findings from empirical research, and their effectiveness has not been rigorously evaluated. Although we feel that there are no quick and simple solutions, our results suggest that some policies may effectively increase the representation of women in science and improve the work experiences of women scientists. For example, colleges and universities can institutionalize programs to actively recruit women from non-S/E majors to the S/E educational trajectory and to address the educational and social needs of the individuals who follow the entry route to S/E education. To mitigate the difficulties of combining an S/E career with family obligations for women (and men), many policies that have been advocated (Hochschild 1989) to help working women in general may be adopted for women scientists in particular. For example, arrangements such as job-sharing and flexible work schedules may enable woman scientists to keep their research agenda moving forward while they care for young children. Quality childcare at the site of employment would ease the emotional and temporal burden of childcare responsibilities for working women, enabling them to focus on their work. We believe that such structural accommodations would improve the disciplines of science and engineering by enabling the participation and intellectual contribution of individuals, both women and men, who wish to be active parents as well as active scientists.

These policy suggestions are not new, and we are fully aware that they alone will not bring about gender equality in science. Women's underrepresentation in S/E has deep social, cultural, and economic roots that will not be transformed by a few isolated policy interventions or programs. Rather, we believe that increasing women's representation in S/E requires many social, cultural, and economic changes that are large in scale and interdependent.

In this regard, we note that women *have* indeed made significant and relatively rapid progress in science and engineering. We reported in Chapter 7, for example, that women have increased their representation among S/E degree recipients and in the S/E labor force. In Chapter 9, we also showed that between the late 1960s and the early 1990s women scientists dramatically improved their structural position in the academic S/E labor force, significantly closing the gap with men on such dimensions as institutional affiliation, research resources, teaching responsibilities, and publication productivity. To some observers, these documented improvements in women's representation and status in S/E still may be too slow and too little. To those critics, we offer three responses. First, there is no doubt that there is ample room for further improvement, and that the pace of improvement can and should be sped up. This is particularly true when science and engineering are compared to other high-status professions, such as medicine and law. Second, the improvements in women's representation and status in science and engineering in recent decades are real, substantial, and irreversible. We venture to say that they would have been unthinkable only four or five decades ago. Once these trends have started, they are likely to continue into the future. Finally, history has shown that societal changes are often gradual. A successful science career takes a long time to form, through education and training, and a long time to complete. Thus, it is a simple demographic impossibility to equalize the representation by gender among those at advanced career stages of S/E careers in a short period of time. When women increase their representation in the S/E labor force, their age structure is necessarily young (as shown in Chapter 7); it takes time for the impact of the change to be fully realized.

Despite the progress, it remains the case that women are still underrepresented in science and engineering. That individual "choices" result in women's lower likelihood to pursue S/E careers in the aggregate gives credence to social psychological explanations. In the classic Wisconsin status attainment model, educational and occupational aspirations are conceptualized as mediating mechanisms for such background factors as parents' socioeconomic status, an individual's own cognitive ability, and the influences of significant others (Sewell, Haller, and Portes 1969). It has been suggested that gender differences in career aspirations are largely responsible for differences in the career outcomes between men and women (e.g., Turner 1964). Some of the results of our study support this proposition: we found significant gender differences in aspirations for S/E education (in Chapter 3) and their consequences for gender differences in the achievement of an S/E bachelor's degree (in Chapter 4). To generalize our limited results to the broader life course, we conjecture that social psychological factors may play a prominent role in generating gender differences in career processes and outcomes in S/E. For example, over the life course men and women may react differently to career setbacks, with women more likely than men to forgo their career goals altogether and to replace them with family responsibilities. Carr (2000) vividly describes such gender differences based on her recent interviews with the original respondents of the Wisconsin Longitudinal Study.[2] Social psychological explanations may be particularly relevant to gender differences in S/E careers, given that S/E training is extensive and S/E work sometimes requires long hours, especially in the early career years when family responsibilities are also the most time-consuming and emotionally demanding. This conjecture is not new, as the "theory of limited differences" (Cole and Singer 1991) also hypothesizes social psychological factors as concrete mechanisms responsible for accumulating and amplifying small gender differences in S/E careers.

However, it would be naïve to attribute gender differences in social psychological factors to innate or natural differences between males and females. Indeed, as sociologists, we believe such gender differences are generated and reinforced by the social structures in which individuals are situated and the networks of interaction in which they participate. Causal mechanisms include socialization by such agents as parents, teachers, peers, and media, role modeling, and perhaps overt and covert practices of gender discrimination. Thus, we return to our earlier statement that to increase women's representation in science ultimately entails fundamental changes at the societal level. In our earlier work (Xie and Shauman 1997), we showed that an increase in the proportion of women in certain professions that were once male-dominated can induce more girls to aspire to these professions. That is, success breeds future success, in the sense that young cohorts of women see and capitalize on opportunities in occupational areas where preceding cohorts of women have been successful. It is plausible that women's successful inroads to law and certain areas of medicine (such as gynecology and pediatrics) have inspired career-oriented young women to pursue these professions. Although the increase of women in science and engineering may be more gradual by comparison, the long-term trend is sharply upward and considerable and will have a similar inducing effect on the participation of future generations of talented young women in science and engineering.

Directions for Future Research

Our research sheds new light on the structure of the S/E career trajectory and the experiences of women and men who participate in it. In our view, the main contribution of our study lies in the new and rich empirical evidence that has been uncovered from many large and nationally representative datasets. Our empirical results enabled us to dispel some entrenched but flawed ideas about the causes of the underrepresentation of women in science and point to the promise of other explanations. Obviously, there is much more to be learned on the topics we covered in this book. In this sense, our study should be a stimulus for future research in this area.

A significant step for future research will be to take seriously the ample evidence we have presented. We hope that future discourse, theoretical or speculative, on women in science is informed by the empirical facts that have emerged from our study. Taking on the questions that are raised but unanswered by our research will also move research on women in science forward. For example, our analyses showed that the gender gap in the likelihood that a high school student aspires to a science career cannot be explained by differences in achievement, coursework, or familial influences. Given the critical importance of aspirations for later educational decisions and outcomes, the causes of this large gender gap should receive further research attention. Furthermore, we found that most of the observed gender differences in research productivity are attributable to gender differences in structural location and access to research resources. This finding calls for the examination of why women and men scientists are allocated to different structural positions. Filling these and other gaps in our work will significantly advance the collective understanding of the causes of gender inequality in science.

Future research should also aim to overcome the limitations of our research. They are numerous, and we trust that critical readers will identify and exploit them. In our opinion, the most serious limitation, one that actually encompasses others, is that our empirical results are essentially descriptive in nature and hence subject to different interpretations. We encourage future researchers to explore and ascertain the causal mechanisms for the empirical results presented in the book and to test speculative hypotheses suggested in our work and in the literature. We realize that this will be a difficult task and likely will entail the collection of newer and better data. In the following, we discuss three specific limitations of our study and suggest ways to overcome them.

First, our study is based on data from the United States only. Much could be learned from comparative analyses of the career experiences and outcomes of women scientists in the United States and those in European and Asian countries. For example, a comparative analysis involving countries with different childcare arrangements may answer questions about the influence of more readily available childcare on the career mobility of women scientists with children. Second, our study focuses mainly on the influences of individual and familial characteristics, especially in the early chapters, and it largely neglects the influence of social factors such as school influences. While we do examine the influence of some social structural characteristics in the later chapters of the book, much more work needs to be done to specify the social influences on the process of becoming a scientist and the experiences and outcomes of those who are active in the S/E labor force. Third, our research did not explicitly examine the effect of gender discrimination on the participation, experiences, and outcomes of women in S/E education and occupations.[3] A number of high-profile cases of both blatant discrimination (such as neurosurgeon Frances Conley's allegations of sexism and resignation from Stanford University; see Gross 1991; Libman 1991) and structural discrimination (such as the admission of long-term discrimination against female science faculty at MIT; see Goldberg 1999; Leo 1999; Wilson 1999) are evidence that both types of discrimination persist and are experienced by individual women scientists and engineers. In addition, although the aggregate representation of women in the S/E labor force has significantly increased, women scientists may still find themselves to be token women in their work settings and subject to the negative pressures and interactions that tokenism entails (Kanter 1977). Empirically measuring the occurrence, causes, and consequences of discrimination against women scientists and engineers is therefore integral to a fuller understanding of the career processes and outcomes of women in science.

Although this book is concerned only with women in science and engineering, we hope that the expansive research design of our study contributes both empirically and methodologically to the study of labor force gender stratification, broadly defined. Our research illuminates the life course processes that at times facilitate, and at times inhibit, the career development of women relative to men. Our results speak directly to career development in science, but we suspect that these processes are common to many professional career trajectories. Thus, our approach to the study of women in science may serve as an example for the understanding of gender inequality in other professions.

Endnotes for Chapter 11

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[1] Of course, that women take major responsibility for childcare is an undeniable form of within-household gender stratification which benefits the husband and disadvantages the wife. However, we here suggest an important mechanism through which this stratification operates--children. When children are not present, our study suggests women scientists/engineers do not seem to suffer from marriage.

[2] Note these respondents were high school seniors in 1957. Women's economic role has dramatically expanded for more recent cohorts.

[3] Rather, we tackled the issue of discrimination implicitly using a conventional residual approach (e.g., Cole 1979), in which the residual gender difference after statistically adjusting for explanatory factors is taken as suggestive of the upper bound of the discrimination effect.